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APPLICATION NUMBER: *60/485,891*
FILING DATE: *July 09, 2003*
RELATED PCT APPLICATION NUMBER: *PCT/US04/17176*

By Authority of the
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT und r 37 CFR 1.53 (c).

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17513 U.S. PTO 60/485091 07/09/03

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
JILL	MacDONALD BOYCE	MANALAPAN NJ 07726
JOAN	LLACH	PRINCETON NJ 08540

☐ *Additional inventors are being named on the _____ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

VIDEO ENCODER WITH LOW COMPLEXITY NOISE REDUCTION

CORRESPONDENCE ADDRESS

Direct all correspondence to:

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☒ Firm *or* Individual Name	JOSEPH S. TRIPOLI, THOMSON LICENSING INC.				
Address	PATENT OPERATIONS.				
Address	P. O. BOX 5312				
City	PRINCETON	State	NJ	ZIP	08543-5312
Country	USA	Telephone	609-734-6800	Fax	609-734-6888

ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages* [4] ☐ CD(s), Number [ ]

☒ Drawing(s) *Number of Sheets* [4] ☐ Other (specify) [ ]

☐ Application Data Sheet. See 37 CFR 1.76

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☐ Applicant claims small entity status. See 37 CFR 1.27.

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FILING FEE AMOUNT ($) [160]

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

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Respectfully submitted,
SIGNATURE ____________ Date [08 JUL 03]

TYPED or PRINTED NAME ROBERT B. LEVY REGISTRATION NO. *(if appropriate)* [28,234]

TELEPHONE 609 734-6920 Docket Number: [PU030197]

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☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 160

Complete If Known	
Application Number	
Filing Date	HEREWITH
First Named Inventor	JILL MacDONALD BOYCE et al.
Examiner Name	
Group / Art Unit	
Attorney Docket No.	PU030197

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1002	330	2002	165	Design filing fee	
1003	520	2003	260	Plant filing fee	
1004	750	2004	375	Reissue filing fee	
1005	160	2005	80	Provisional filing fee	160

SUBTOTAL (1) ($) 160

2. EXTRA CLAIM FEES

			Extra Claims		Fee from below		Fee Paid
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Independent Claims		-3 ** =	0	X		=	0
Multiple Dependent				X		=	0

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	84	2201	42	Independent claims in excess of 3
1203	280	2203	140	Multiple dependent claim, if not paid
1204	84	2204	42	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

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1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet.	
1053	130	1053	130	Non-English specification	
1812	2,520	1812	2,520	For filing a request for reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	410	2252	205	Extension for reply within second month	
1253	930	2253	465	Extension for reply within third month	
1254	1,450	2254	725	Extension for reply within fourth month	
1255	1,970	2255	985	Extension for reply within fifth month	
1401	320	2401	160	Notice of Appeal	
1402	320	2402	160	Filing a brief in support of an appeal	
1403	280	2403	140	Request for oral hearing	
1451	1,510	1451	1,510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive – unavoidable	
1453	1,300	2453	650	Petition to revive – unintentional	
1501	1,300	2501	650	Utility issue fee (or reissue)	
1502	470	2502	235	Design issue fee	
1503	630	2503	315	Plant issue fee	
1460	130	1460	130	Petitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17 (q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	
1809	750	2809	375	Filing a submission after final rejection (37 CFR § 1.129(a))	
1810	750	2810	375	For each additional invention to be examined (37 CFR § 1.129(b))	
1801	750	2801	375	Request for Continued Examination (RCE)	
1802	900	1802	900	Request for expedited examination of a design application	

Other fee (specify) ____

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SUBTOTAL (3) ($) 0

SUBMITTED BY

				Complete *(if applicable)*	
Name (Print/Type)	ROBERT B. LEVY	*Registration No. Attorney/Agent)*	28,234	*Telephone*	609/734-6820
Signature				*Date*	9 July 2003

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VIDEO ENCODER WITH LOW COMPLEXITY NOISE REDUCTION

The invention provides a method for performing noise reduction inside of a video compression encoder with low incremental complexity. The motion estimation portion of a video encoder is additionally used for the noise reduction process, with multiple motion estimation decision sets stored so that multiple predictors may be used in motion-compensated temporal filtering.

Noise reduction prior to video encoding can improve the quality of video encoding of a noisy video sequence at a given bitrate. However, the best noise reduction techniques are very computationally complex to implement. In the invention, a noise reduction function can be added to a video encoder with very low incremental complexity.

It is well understood that noisy video sequences are more difficult to compress using standard video compression techniques, than are clean video sequences at a given bitrate. Noise reduction can be applied as a pre-processing function applied prior to video compression, as shown in Figure 1. In such a system, noise reduction is applied to a sequence of input pictures, creating a sequence of noise reduced pictures. The noise reduced pictures are then encoded using a video encoder, creating a compressed video bitstream.

Spatial and/or temporal filtering have been used in prior noise reduction methods. Temporal filtering involves applying a filtering function, such as an average, to the pixels from several different input pictures to create filtered pixels. Temporal filtering of video sequences generally falls into one of two categories, motion compensated or non-motion compensated. For video sequences containing motion, the use of motion compensated methods generally outperforms non-motion compensated methods. Motion compensated methods however are generally the most computationally expensive of the classes of methods.

Most video compression standards (MPEG, H.263, H.264) use motion estimation and compensation in the encoding process.

The H.264 video compression system (also referred to as JVT or MPEG AVC) uses tree-structured hierarchical macroblock partitions. Inter-coded 16x16 pixel macroblocks may be broken into macroblock partitions, of sizes 16x8, 8x16, or 8x8. Macroblock partitions of 8x8 pixels are also known as sub-macroblocks. Sub-macroblocks may be further broken into sub-macroblock partitions, of sizes 8x4, 4x8, and 4x4. An encoder may select how to divide the macroblock into partitions and sub-macroblock partitions based on the characteristics of a particular macroblock, in order to maximize compression efficiency and subjective quality.

Multiple reference pictures may be used for inter-prediction, with a reference picture index coded to indicate which of the multiple reference pictures is used. In P pictures (or P slices), only single directional prediction is used, and the allowable reference pictures

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are managed in list 0. In B pictures (or B slices), two lists of reference pictures are managed, list 0 and list 1. In B pictures (or B slices), single directional prediction using either list 0 or list 1 is allowed, or bi-prediction using both list 0 and list 1 is allowed. When bi-prediction is used, the list 0 and the list 1 predictors are averaged together to form a final predictor.

Figure 2 shows a normal video encoding system block diagram for use with H.264 or similar video compression systems. For an H.264 encoder, the motion estimation process inputs are the input video sequence pictures and the previous coded pictures, which are stored in the reference picture stores. For each macroblock in a current picture, the motion estimation process compares the current macroblock with some pre-determined number of reference pictures. A macroblock mode, which indicates the breakdown of the macroblock into the various partitions sizes, is output for each macroblock. For each macroblock partition, a reference picture index is output. For each macroblock partition or sub-macroblock partition, a motion vector is output. The motion estimator has considerable freedom to decide what are the best macroblock mode, reference picture indices and motion vectors for a macroblock, with the goal to create a good predictor for the current picture, so that the current picture may be encoded efficiently. Once these decisions are made in the motion estimation process, a predictor is formed in the motion compensation process, and the predictor is subtracted from the input picture, to create a difference picture. The difference picture is coded using a block transform, quantizer, and entropy coder. Inverse quantization and inverse transform are applied, and the coded/decoded picture is stored in the reference picture stores for use in the coding of later pictures.

References:

[1] J. Brailean, R. Kleihorst, S. Efstratiadis, A. Katsaggelos, R. Lagendijk, "Noise Reduction Filters for Dynamic Image Sequences: A Review," Proceedings of the IEEE, Vol. 83, No. 9, Septeber 1995, pp. 1272-1292.

[2] J. Boyce, "Noise Reduction of Image SEquences using Adaptive Motion Compensated Frame Averaging," in Proc. ICASSP, Mar 1992, vol. 3. pp. 461-464.

[3]P. van Roosmalen, A. Kokaram, J. Biemond, "Noise reduction of image sequences as prepreccessing for MPEG2 encoding", European Conference on Signal Processing (EUSIPCO '98), Sept. 1998, Vol. 2., pp.1061-1064.

[4] T. Wiegand, JVT Study of Final Committee Draft, Dec 5-13, 2002, ftp://ftp.imtc-files.org/jvt-experts/2002_12_Awaji/JVT-F100d1ncm.zip

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In this invention, the motion estimation function of a video encoder is also used to perform noise reduction. The incremental complexity of performing noise reduction as part of a video encoder is very small compared to that of a standalone video noise reduction system. For noisy video sequences, this invention can significantly improve the compressed video quality at a particular bitrate as compared to a normal video encoder.

This invention can be used with any block-based motion compensation video compression system. However the best results are for a compression systems like H.264 that use multiple reference pictures, because the motion estimation functions for the multiple reference pictures can be re-used in both the encoder and noise reducer, allowing multiple pictures to be used in the noise reduction filtering process.

Figure 3 shows a video encoder with noise reducer, in accordance with the present invention. Similar to the prior art system in Figure 2, the motion estimation process inputs are the input video sequence pictures and the previous coded pictures, which are stored in the reference picture stores. However, instead of outputting a single best macroblock mode for the macroblock, a reference picture index for the macroblock

partition and motion vector for a macroblock partition or sub-macroblock partition, in accordance with the current invention the output is the best N sets of (Mode, RefPicIndex, and MV) for the partitions and sub-macroblock partitions of the macroblock, referred to as motion estimation decision sets.

Figure 4 shows a flow chart of the noise reduction process for the picture to be coded, in accordance with the current invention. The macroblocks in the picture are looped with loop index mb. For each macroblock, motion estimation is performed, with N motion estimation decision sets stored. Then, noise reduction is applied to the macroblock, using the stored N motion estimation decision sets. The noise reduction process is described in more detail below. Then video encoding of the macroblock is performed. First, the motion compensation process creates a predictor for the macroblock using the first of the N stored motion estimation decision sets, which is considered to be the best of the sets. This prediction is subtracted from the filtered picture, with the difference picture transformed, quantized, and entropy coded, and then inverse quantized and inverse transformed and stored in the reference picture stores.

In one embodiment of the present invention, the N motion estimation data sets are required to each use a different reference picture index for each macroblock partition.

The N motion estimation decision sets are input to the noise reduction process. Figure 5 shows a flowchart of the noise reduction process. Each pixel in the block is looped through, with loop index p. Each of the N motion estimation decision sets are looped through, with look index i. For each i, a predictor, pred[i], is formed for the pixel by performing motion compensation using the i-th motion estimation decision set. A difference measure is computed which compares the values of the current pixel pic[p] with the predictor, pred[i]. This difference measure may include luma and/or chroma values in the calculation. An example difference measure is the absolute difference value. If the difference measure is below a threshold, the predictor is added to the filtering set, fset, to be used in the noise reduction filtering operation.

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After all N motion estimation data sets have been threshold tested to form the complete filter set, fset, a filtering operation is performed on fset. The filtering operation is separately performed on luma samples and on associated samples of both chroma components. Any of several different filter functions may be used in the noise reduction filtering operation, such as computing an average, a weighted average, or a median. The filtering operation may also include spatial neighbors in the computation. The spatial neighbors may also be compared with a threshold to consider whether to include the spatial neighbors in the filtering operation. The result of the pixel filtering operation is placed in the filtered picture, as Filt_pic[p]. The filtered picture, Filt_pic is then used as the input to the rest of the video encoding process.

Figure 3 illustrates a particular embodiment of the current invention where the filtered pictures are stored in filtered picture stores, and used as the inputs to the noise reduction process when noise reducing later pictures. Alternatively, the original input pictures of the reference picture stores may be used as inputs to the noise reduction process.

For macroblocks in intra (I) pictures, spatial-only filtering may be performed. Alternatively, the motion estimation and noise reduction processes described earlier may be performed, but with the video encoding portion performing intra-only encoding, and hence not making use of the motion estimation decision set chosen in the motion estimation set. For a hardware encoder, there is little additional complexity involved in performing motion estimation on an I picture, as the existing motion estimation components already exist and would otherwise be unused.

In an embodiment of the current invention, spatial filtering may be applied to the input pictures prior to the motion estimation process. Figure 6 illustrates a system where spatial filtering is applied to input pictures, prior to encoding and motion estimation. For I pictures, motion estimation is not used, and the input to the encoding process is selected to be the spatially filtered input pictures. For P and B pictures, motion estimation is performed using the spatially filtered input pictures as input.

Possible Claims:

1. Encoder and noise reducer that share the same motion estimation function.
2. Storing more than one motion estimation decision set from the motion estimation function of the encoder, to be used by a motion compensated temporal filtering operation.
3. Use of threshold in decision whether or not to include a predictor in the noise reduction filtering operation.
4. Use previously coded pictures as references in motion estimation, but applying motion estimation decisions (motion vectors, etc.) to filtered pictures for noise reduction.
5. Applying spatial filtering to the input pictures before motion estimation which is used for motion-compensated temporal filtering.

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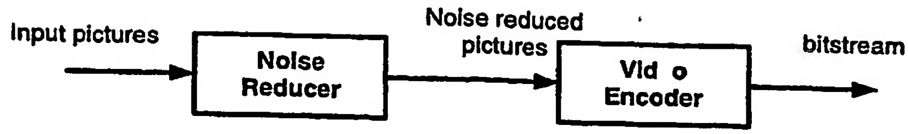

Figure 1. Standard Video Encoder

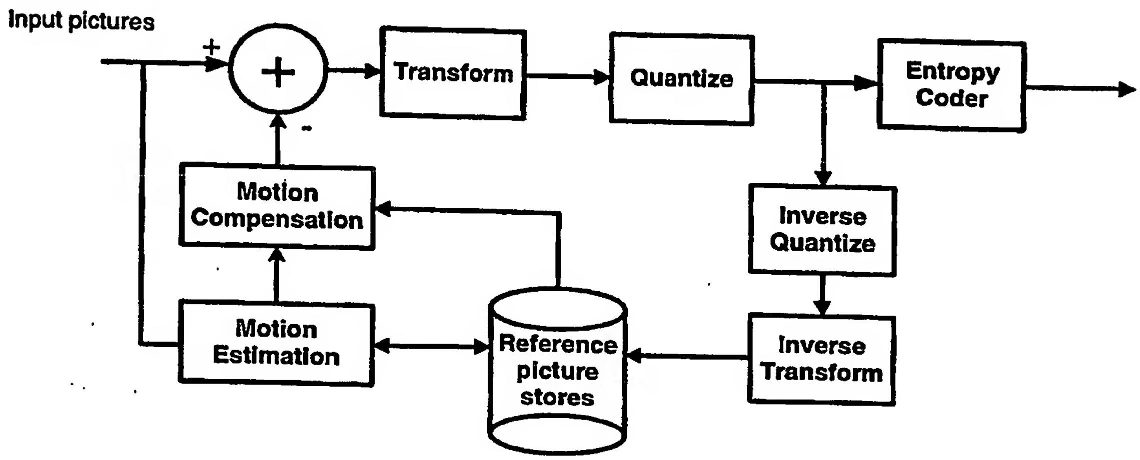

Figure 2. Standard Video Encoder

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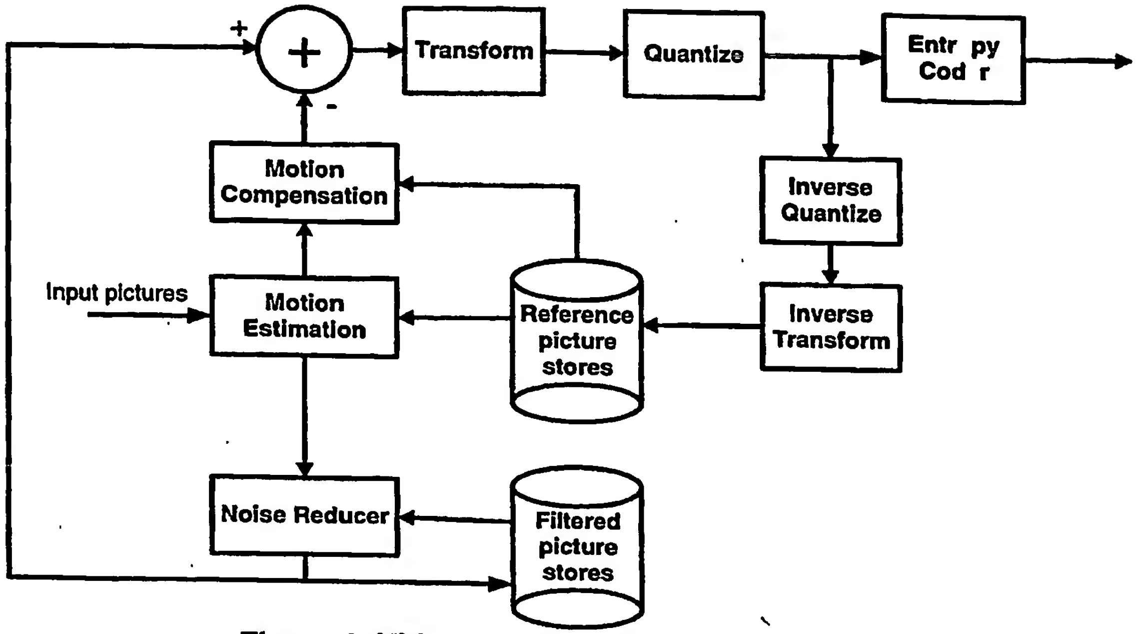

Figure 3. Video Encoder w/ Noise Reducer

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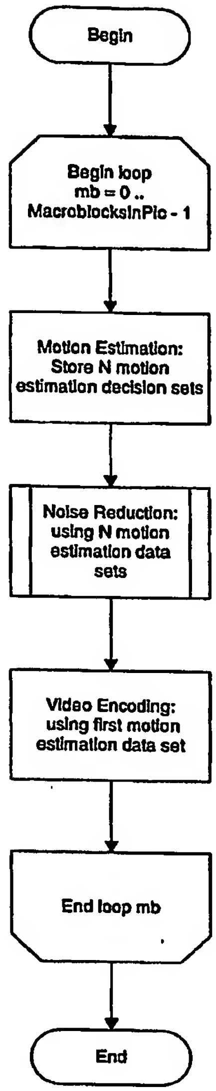

Figure 4. Flowchart of Encoder/Noise Reducer

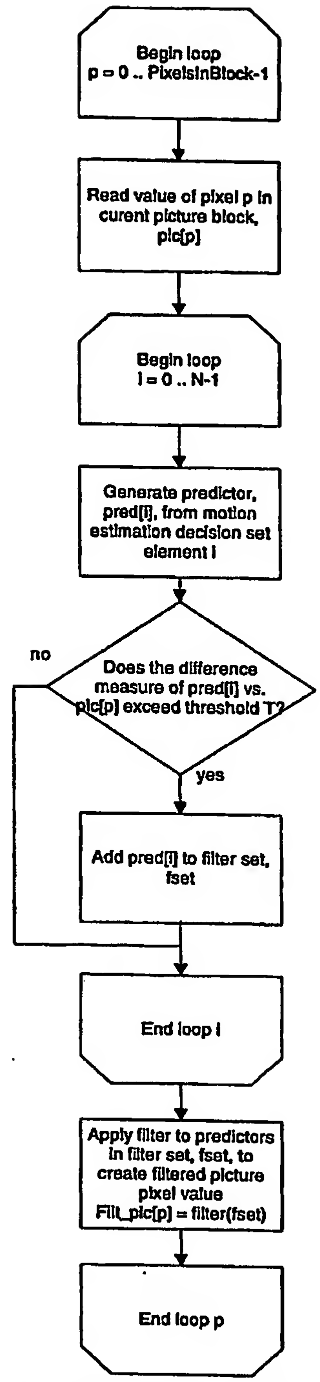

Figure 5. Flowchart of Noise Reduction process

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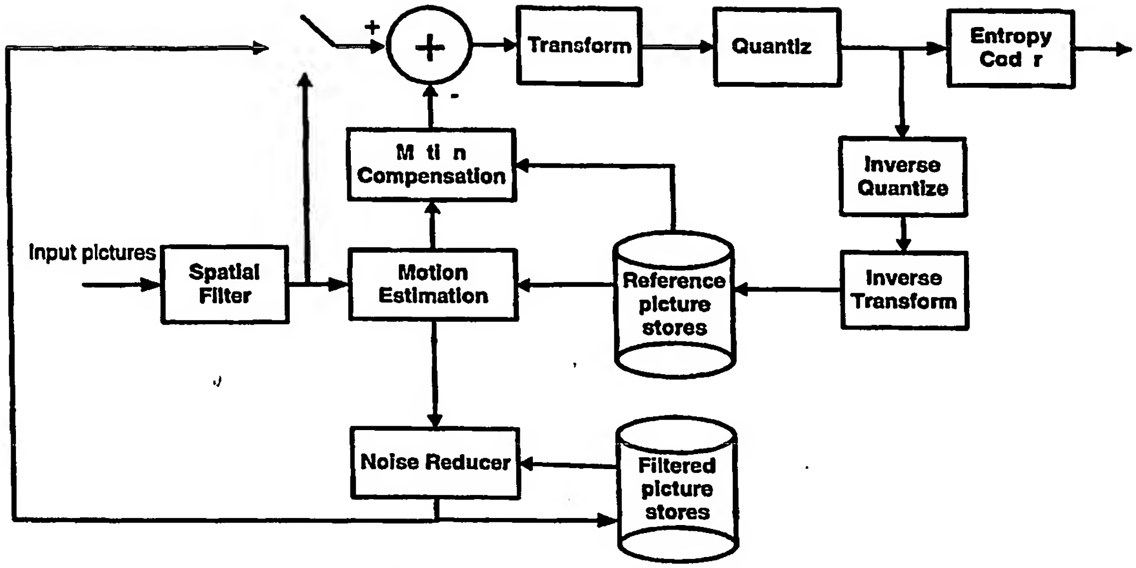

Figure 6. Video Encoder w/ Noise Reducer and Spatial Filtering